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Technical Report N-60
September 1962

Integrated Installation Noise Contour System

ACOUSTIC DIRECTIVITY PATTERNS FOR ARMY
WEAPONS: SUPPLEMENT 1

AD A121665

by
Paul D. Schomer

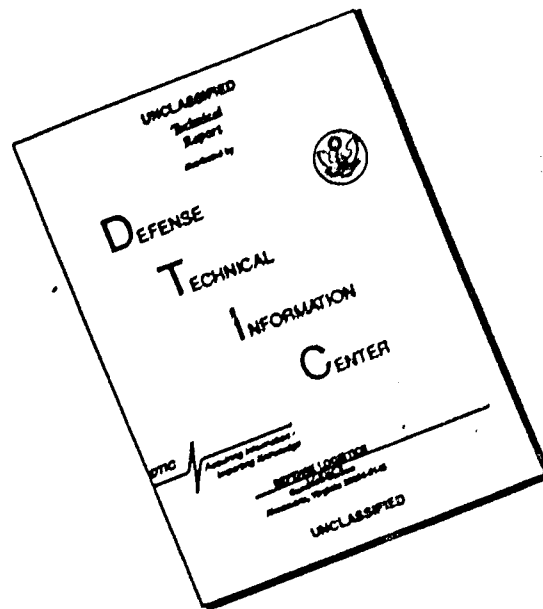
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FOREWORD

This research was conducted for the Directorate of Military Programs, Office of the Chief of Engineers (OCE), under Project 4A762720A896, "Environmental Quality Technology"; Task A, "Installation Environmental Management Strategy"; Work Unit 011, "Integrated Installation Noise Contour System." The OCE Technical Monitor was Mr. Gordon Velasco, DAEN-MPE-1.

The work was performed by the Environmental Division (EN) of the U.S. Army Construction Engineering Research Laboratory (CERL). Dr. R. K. Jain is Chief of CERL-EN.

COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.



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ACOUSTIC DIRECTIVITY PATTERNS FOR ARMY WEAPONS: SUPPLEMENT 1

1 INTRODUCTION

Background

On 20 May 1981, the Army instituted the Installation Compatible-Use Noise Zone Program (ICUZ). Under ICUZ, Army installations will work with the local civilian community to find ways to prevent or lessen the encroachment of off-installation housing and other noise-sensitive land uses into areas that are, or are likely to be, impacted by Army training noise.¹

Vital to the success of the ICUZ program is a noise-prediction computer tool developed by the U.S. Army Construction Engineering Research Laboratory (CERL). The Integrated Noise Contour System (INCS) creates distance-scaled noise contours using data on the type, frequency, and time of training operations; weapon types and charge sizes; and target and firing point locations. These contours, when overlaid on a map of an installation and its environs, identify existing or potential conflicts between noise levels produced by training operations and noise-sensitive land uses on or near an installation. Using BNOISE 3.2, the blast noise prediction computer program associated with INCS, contours also can be created that predict how changes in training range operations, siting, use intensity, and weapon types will alter an installation's noise-impact profile.² The Army Environmental Hygiene Agency (AEHA) can make noise predictions for any Army installation using CERL's INCS/BNOISE 3.2 program.

One important data type needed for INCS/BNOISE 3.2 is the individual acoustic directivity pattern associated with most impulse-noise producing weapons in the Army inventory. These patterns form a standard module of data for the INCS/BNOISE 3.2 prediction program.

CERL Technical Report N-60 lists directivity pattern data obtained during tests at Fort Sill, OK, for many weapons used routinely in Army training (Table 1).³ This

supplement to that report contains directivity pattern data for the LAW and TOW antitank weapons and three regularly used weapon simulators.

Purpose

The purpose of this study was to determine the acoustic directivity patterns of the LAW and TOW antitank weapons and three regularly used, impulse-noise producing weapon simulators.

Approach

Noise measurements were made on the LAW and TOW antitank weapons and on three flash and boom simulators at Fort Carson, CO. The measurement method was basically the same as that described in CERL Technical Report N-60. Weapon firings were interspersed with detonations of C-4 plastic explosive. The C-4 was used to "calibrate" the site and allow data to be corrected for wind and terrain effects.

Mode of Technology Transfer

The directivity patterns obtained as a result of this study have been added to the INCS/BNOISE 3.2 input data bank and are available for use by AEHA and all Department of Defense activities.

Table 1
Weapons Tested (Fort Sill, OK)

Weapon Name	Model
8-in. self-propelled	M110A1
105-mm tank	M60
4.2-in. mortar	M30
81-mm mortar	--
106-mm recoilless rifles	M40A1
90-mm recoilless rifles	M67
105-mm howitzer	M102
155-mm howitzer	M109
8-in. howitzer	M110
152-mm Sheridan (tank gun)	M551
155-mm howitzer	M114
155-mm howitzer	M109A1

2 DATA COLLECTION

Measurements were performed at Fort Carson, CO. The antitank weapon data source was the normal training operations of an armor combat support company. The simulators were activated especially for the CERL measurements. The test site was an open grassy field, the standard type of training range at Fort Carson. An abbreviated test plan is given in Appendix A.

Test Sequence

Table 2 lists the two weapons and three simulators measured for blast noise during the Fort Carson test. The

¹Paul Schomer, "Noise Impact Prediction and Control," *Military Engineer*, Volume 74, Number 479 (April 1982).

²Paul D. Schomer et al., *Blast Noise Prediction Volume I: Data Bases and Computational Procedures*, and Lincoln M. Little et al., *Volume II: BNOISE 3.2 Computer Program Description and Program Listing*, Technical Report N-98/ADA099440 and ADA099535 (U.S. Army Construction Engineering Research Laboratory (CERL), March 1981).

³P. D. Schomer, L. M. Little, and A. B. Hunt, *Acoustic Directivity Patterns for Army Weapons*, Technical Report N-60/ADA080225 (CERL, January 1979).

Table 2
Weapons Tested and Event Numbers
(Fort Carson, CO)

27 March 1981		2 April 1981		3 April 1981	
Event No.	Weapon	Event No.	Weapon	Event No.	Weapon
1	C-4	1	C-4	21	C-4
2	TOW	2	C-4	22	C-4
3	TOW	3-7	Artillery simulator	23	LAW
4	C-4	8	C-4	24	LAW
5	TOW	9	C-4	25	LAW
6	TOW	10-14	Hand grenade simulator	26	C-4
7	C-4	15	C-4	27	C-4
8	C-4	16-18	Artillery flash simulator		
		19	C-4	28	LAW
		20	C-4	29	LAW
				30	LAW
				31	C-4
				32	C-4

main body of the test used C-4 plastic explosive as an omnidirectional calibration source. The test sequence consisted of one blast of C-4 followed by one or more events from the weapon or device under test. The C-4 sound-pressure level contours were used to correct for the effects of wind and/or terrain. This is essentially the same procedure used during the original Fort Sill measurements.

Measurement Apparatus

Each weapon or simulator was measured separately. For each measurement series, microphones were deployed in a concentric ring. A radius of about 600 ft (183 m) was used for the antitank weapon measurements, and a radius of 250 ft (75 m) was used for the simulator devices. Each test-series ring consisted of six microphones placed at 60° intervals around the firing point, as shown in Figure 1.

The microphones were Endevco piezoresistive transducers close-coupled to CERN-built preamplifiers and line drivers. (Appendix B describes the Endevco device and the CERN preamplifiers.) Each microphone was wired to the CERN mobile field acoustics laboratory, where the signal was recorded on an Ampex PR 2230 14-channel FM recorder. For comparison, a standard B&K-type 4921 outdoor microphone system was located at Station 7, wired to the CERN van, and its signal recorded. However, the peak levels registered by the B&K 4921 system were "clipped," because they were larger than the maximum level capability of the B&K 4921.

During the test, the measurement plan (Appendix A) had to be modified because the simulators and the LAW rocket produced too little noise to be measured at 600 ft (182 m). So, the test radius was changed to 250 ft (72 m). The size of the C-4 calibration was reduced from 5 to 1-lb (2.2 to 0.5 kg).

Calibration

Calibration was performed (1) at the beginning of every new tape, (2) at the end of each tape and/or day, (3) when changes were made in the equipment or equipment placement, (4) when the equipment was first set up, and (5) when any equipment malfunction was suspected. The six Endevco stations were calibrated with a B&K 4220 pistonphone. CERN made special housings for the Endevco microphones so the calibration could be done using standard laboratory and field devices (see Appendix B). At the beginning of each FM tape, the calibration tone was recorded for about 15 seconds at the measurement tape speed of 60 in./second (1524 mm/second). The B&K 4921 system was calibrated initially using the B&K-type 4220 pistonphone. Subsequent calibrations were performed using its internal 1000-Hz electrostatic actuator.

3 DATA REDUCTION

Primary data reduction was done using the CERN-developed True-Integrating Environmental Noise Monitor and Sound-Exposure Level Meter.⁴ This data reduction resulted in a measure of the flat-weighted and C-weighted sound exposure level (FSEL and CSEL). The Norland computing oscilloscope was used to measure flat-weighted and C-weighted peak data for each event. Background noise measurements were also made to ensure that the recorded data were far enough above the noise level to be valid. Appendix C lists analyzed data by event.

⁴Aaron Avnir, et al., *True-Integrating Environmental Noise Monitor and Sound-Exposure Level Meter Volumes I through IV*, Technical Report N-41/ADA000000, ADA000000, ADA000000, and ADA000001 (CERN, May 1979, June 1979, and March 1980).

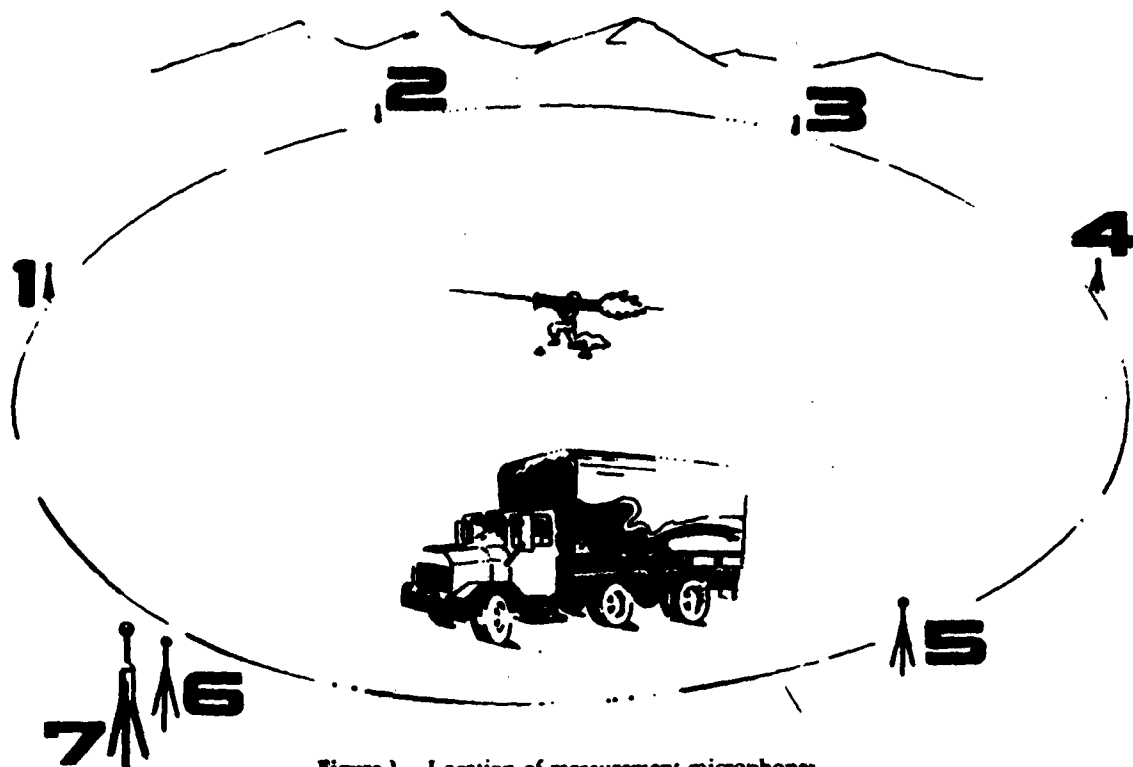


Figure 1. Location of measurement microphones.

Each data event or series of events was first corrected by the adjacent (in-time) C-4 calibration events. A set of numbers was found for the C-4 events just before and after the weapon or device event(s) and used to correct the C-4 data to an omnidirectional, hemispherical (actually circular in the ground plane) radiating source. The event data were averaged by microphone and corrected by the set of numbers found to convert the C-4 to a perfect circular source. These averages are listed in Appendix D. Similar weapons or sources (after correction by adjacent C-4 calibrations) were then combined (energy-averaged by microphone) to form the overall weapon or device directivity pattern. Corrections were made to form a symmetrical pattern. Appendix D lists the resultant data by weapon or device.

Table 3 lists the data as they are included in the BNOISE 3.2 weapons input table. Table 3 is based on the data given in Appendix D. In the table, data for the simulators are adjusted so they are relative to 5 lb (2.2 kg) of C-4 on the ground (as required by BNOISE 3.2), rather than the 1-1/4 lb (0.5 kg) used in the test. A conversion factor of 5 decibels (dB) was used.¹ The reference distance was 250 m. At this distance, 5 lb (2.2 kg) of C-4 exploded on the ground typically produces a CSEL of 119 dB.

¹Paul D. Schomer, et al., *Blast Noise Prediction Volume I: Data Base and Computational Procedures*, Technical Report N-90/ADA099440 (CERL, March 1991).

4 CONCLUSIONS

The report gives the acoustic directivity patterns for the LAW and TOW antitank weapons and three routinely used weapon simulators measured at Fort Carson, CO. These data supplement the pattern data presented in CERL Technical Report N-60. These supplemental pattern data will be included in the weapon directivity pattern load module of BNOISE 3.2 and made available to users of the CERL-developed INCS.

The onsite need to vary the original test plan indicates some of the problems in attempting to specify standard measurements for the directivity pattern of Army weapons. Some of the devices were such that the planned measurement distance had to be reduced from 600 to 250 ft (182 to 76 m). The C-4 calibration charge also had to be reduced from four sticks to 1 stick (i.e., from 5 to 1-1/4 lb [2.2 to 0.5 kg]). Standard measurement procedures cannot be developed without showing sufficient repeatability over time (the same weapon measured in the same place but at different times), repeatability over position (the same weapon measured in different locations at different times), and until enough is known about each type of weapon to adequately specify measurement distances and calibration charge size.

Table 3

Reduced Data by Weapon or Device

80 COLUMN KEY PUNCH TRANSCRIPT LAYOUT SHEET

APPENDIX A: TEST PLAN FOR ROCKET NOISE MEASUREMENTS

Background

A background literature study was performed on the sources and levels of noise generated by rockets. This study indicates that very little far-field data exist on rocket noise emissions other than for the very large ballistic-missile types of rockets. For the small rockets, interest has centered primarily on the noise encountered at the operator's ear. For preliminary work, the Army Environmental Hygiene Agency (AEHA) has equated the pounds of propellant to the far-field pressure in a like manner to explosions of C-4 plastic explosive or TNT. Indeed, some recent work in the United Kingdom by Clayden, Walters, and Hillman supports this concept. They say, "... in the near field, the shock strength depends strongly on the detailed mechanism of the starting process, hence there is some scope for noise reduction, but in the far field it is primarily dependent on the total energy released."⁶ Basically, the small rockets appear to produce most of their noise from the bursting of a plug or membrane when the engine ignites and from the subsequent shock wave formed by the engine burn. However, the small amount of data which do exist indicate a fairly extreme directivity pattern for the noise emissions from small rockets.

To test the preliminary hypothesis that the primary noise of interest was the burst which comes at or just after ignition of the rocket engine, simple measurements were performed on a DRAGON missile at Fort Benning, GA. Typical recorded waveforms are shown in Figure A1. These waveforms are classical shock wave signatures, identical to those generated by explosives. Thus, the literature search and the preliminary measurements at Fort Benning show that (1) small rockets can be modeled identically to other impulsive weapon systems such as armor or artillery and (2) the detailed directivity pattern of each weapon must be measured similarly to those already reported in CERL Technical Report N-60 for most armor and artillery weapon systems.

Purpose

The purpose of these measurements is to gather required data on the noise emissions of small Army rockets. These rockets are characterized by a plug or seal at the motor end which bursts or explodes shortly after ignition. The primary noise to be measured by these tests is that of the burst⁷ explosion of this plug or membrane and the subsequent shock wave formed by the engine burn.

⁶W. A. Clayden, A. G. Walters, A. Hillman, "A Survey of UK Work on Noise and Blowback From Man-Portable Anti-Tank Weapons," paper presented at the TTCPW2 Symposium on In-Bore Dynamics and Intermediate Ballistics, July 7 and 8, 1976, Monterey, CA.

Weapons To Be Measured

1. Primary Weapons
 - a. LAW
 - b. Improved LAW (VIPER)
 - c. TOW
 - d. DRAGON.
2. Second Priority
 - a. STINGER anti-aircraft missile system
 - b. Redeye
 - c. 2.75-in. rocket.
3. Airborne Rockets
 - a. Hellfire (Helicopter Launch to Antitank Missile System)
 - b. M65 (Antitank missile)
 - c. SS-11 missile.

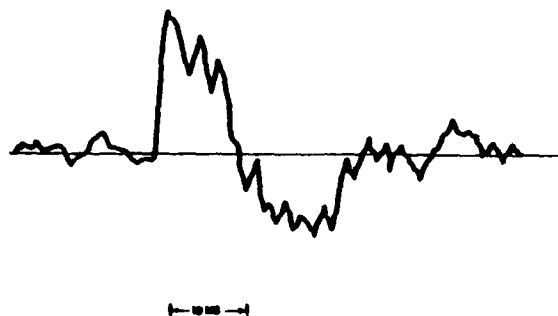


Figure A1. DRAGON missile waveforms (about 100 m to the rear; FM recording).

Test Location(s)

It is desired to make these tests as part of regularly scheduled training or other tests rather than create a special set of tests just for these measurements. Thus, the measurement team will move from site to site at various times in order to accomplish these measurements. To the extent possible, however, it is clearly desirable to measure more than one rocket at the same location in approximately the same timeframe. For proper data, the test site must be a clear, level, open area.

Test Setup

Measurements will be done like those already employed for the directivity patterns of armor and artillery weapons. Specifically, measurements will be made on a ring having a radius of 250 m. Additional measurements will also be made at distances of 500 m, and at one site, to the rear of the rocket at 1000 m. The measurement sites are shown in Figure A2. Most of these sites will be wired by landline to

CERL's instrument van, where FM recordings will be made of the noise signatures. The other sites will be manned and will use Nagra recorders and a special, CERL-developed modulation system.

As with the heavy weapons measurements, 5 lb (2.2 kg) of C-4 set plastic explosive on a post about 3 ft (0.9 m) high will be used to calibrate the measurement site and relate these new measurements to previous weapons measurements and previous sound propagation work by CERL. These C-4 calibration charges are the only requirement CERL has which may in any way affect the conduct or order of other training or tests.

Approximately 5 to 10 measurements are required for each rocket-engine combination.

Support Requirements

CERL will do all the measurements and data analysis. The acoustical data will be gathered by CERL personnel using CERL equipment. In addition to firing the rocket-weapon system, the facility involved will have to supply about one to two personnel trained in demolition to set the C-4 explosive charges and will also be responsible for safety requirements for use of the weapons and for the C-4.

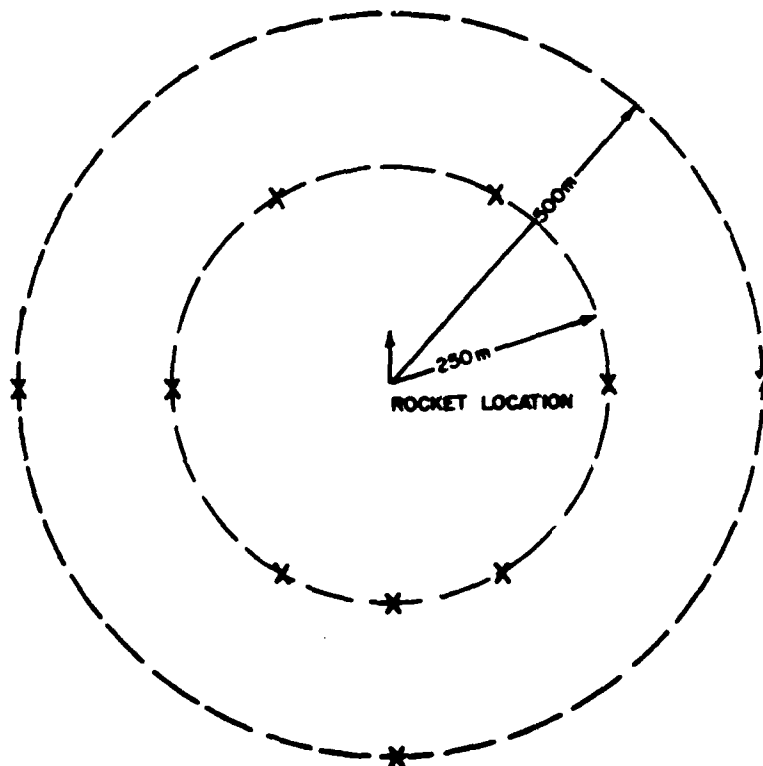


Figure A2. Proposed measurement locations.

APPENDIX B: TEST EQUIPMENT SPECIFICATIONS AND WIRING DIAGRAMS

Table B1
Microphone Line Driver Parts List

R1, R5.....	90K, 1%
R2, R10.....	100K, 1%
R3.....	1.8M, 5%
R4.....	300K, 1%
R6.....	1M, 1%
R7, R8.....	10, 5%
R9.....	10K, 5%
R11, R12.....	12K, 5%
R13, R14.....	47, 5%
C1.....	6-8 μ f
C2.....	not used
C3.....	8.2 pF
C4, C5.....	100 μ f
C6.....	0.01 μ f
C7.....	220 pF
C8, C9.....	not used
Q1.....	SK3024
Q2.....	SK3025
U1.....	LM301AN

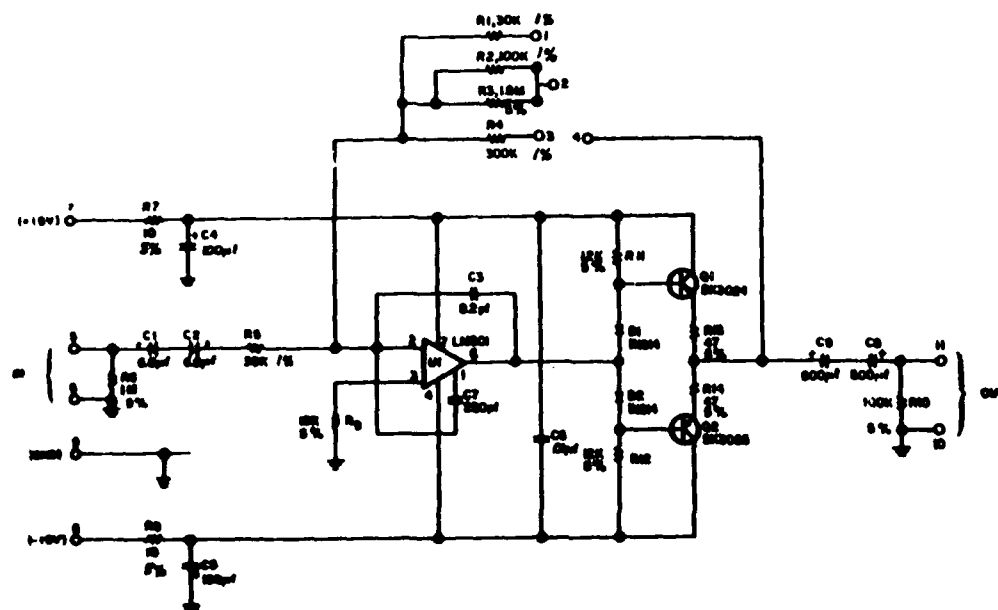
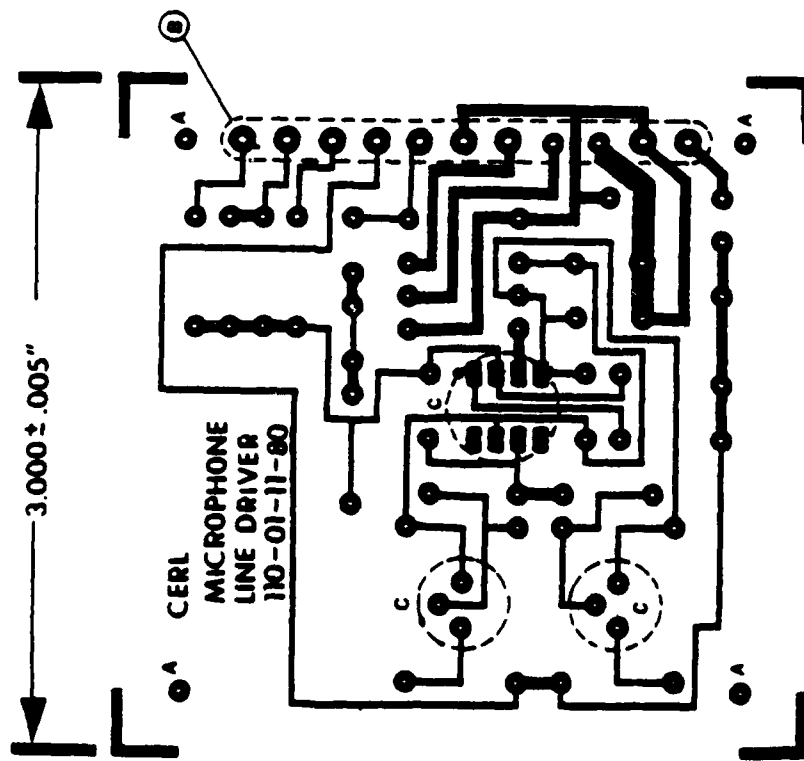
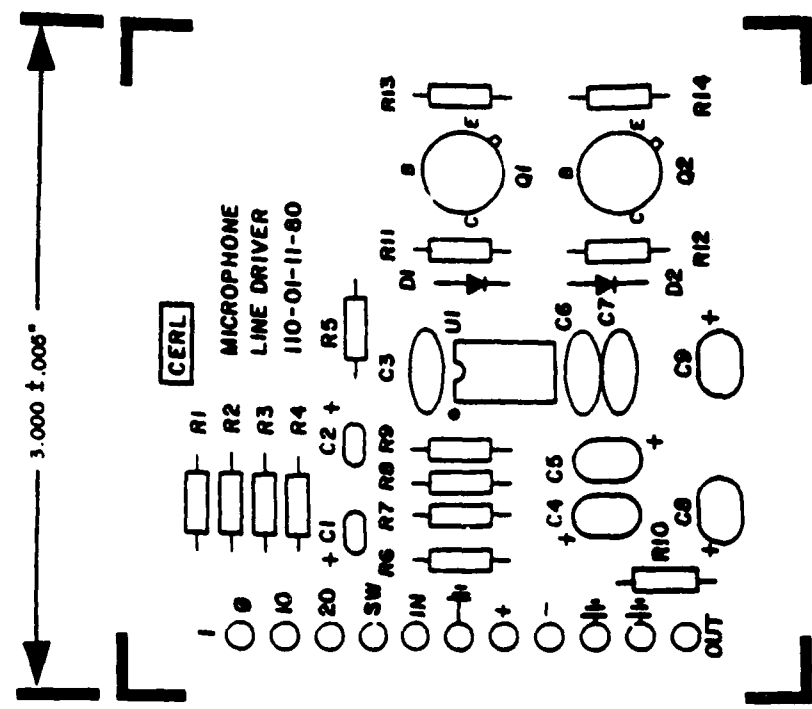


Figure B1. Microphone line driver schematic.



CIRCUIT SIDE FOIL



COMPONENT SILK SCREEN

Figure B2. Microphone line driver printed circuit board.

Table B2
Piezoresistive Microphone Preamplifier Parts List

Gain Desired	R_1	C_1	Maximum
			Sound-Pressure Level
0	Short	30 pf per ceramic disk	190
20	8.1k Ω	20 pf per ceramic disk	170
30	27.6k Ω	10 pf per ceramic disk	160
50	284k Ω	3 pf per ceramic disk	140

Piezoresistive Microphone Preamp

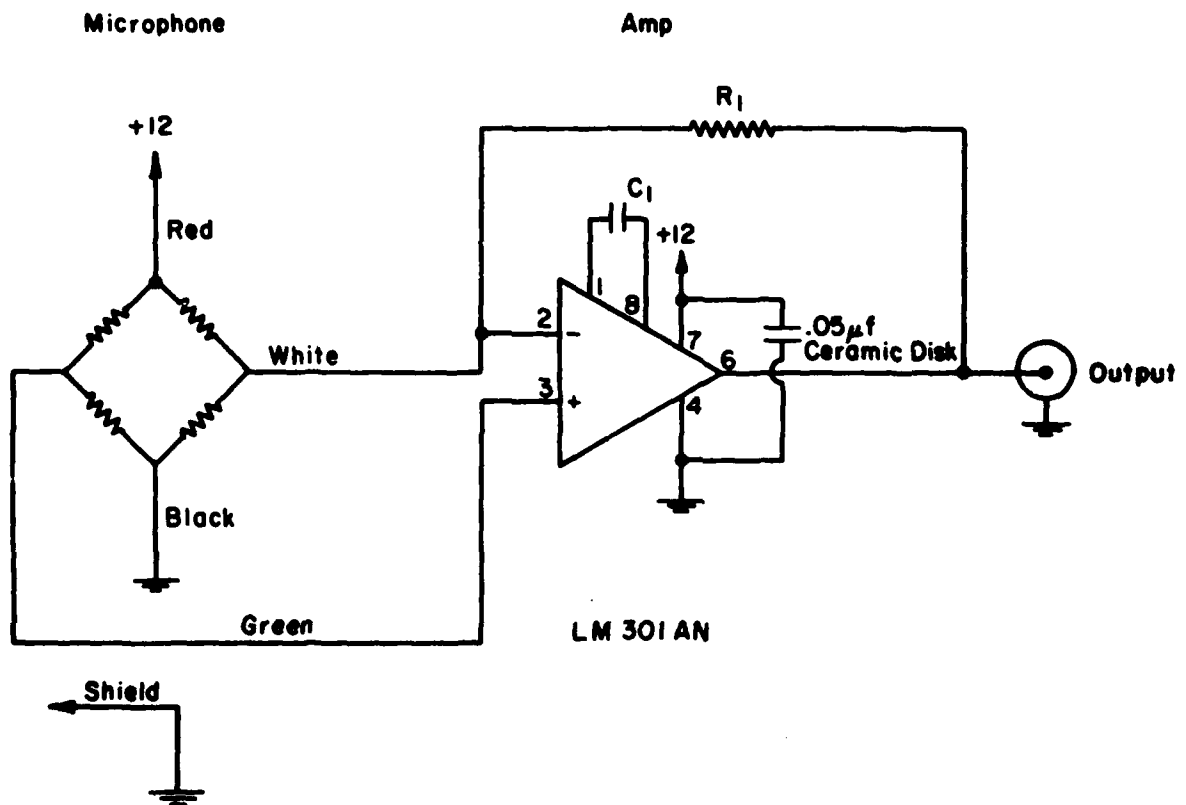


Figure B3. Piezoresistive microphone preamplifier.

SPECIFICATIONS FOR MODEL 8888M1 MICROPHONE
(According to ANSI and ISA Standards)

PERFORMANCE

RANGE	At least 100 to 180 dB SPL
SENSITIVITY (AT 15 Vdc)¹	-110 \pm 3 dB ref 1 V per μ bar (equivalent to 63 rms mV at 180 dB SPL or 218 mV/psi) ¹
RESONANCE FREQUENCY	45 000 Hz, typical
FREQUENCY RESPONSE	Within \pm 1 dB to 5 000 Hz Within \pm 3 dB to more than 10 000 Hz
AMPLITUDE LINEARITY	\pm 0.5 dB, 100 to 180 dB SPL
VIBRATION SENSITIVITY	100 dB SPL at 1 pk g, typical
WARMUP TIME	<30 sec.
BURST PRESSURE	>20 psi

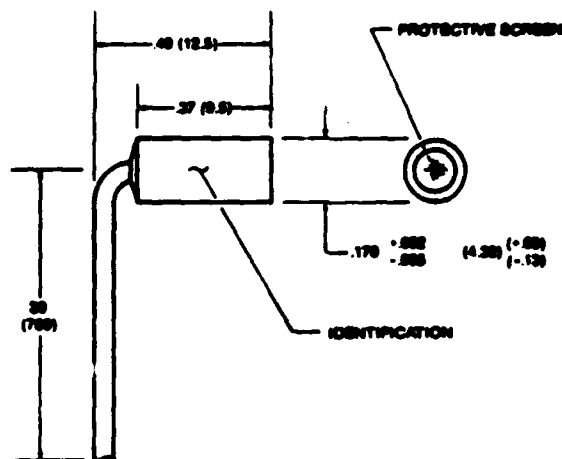
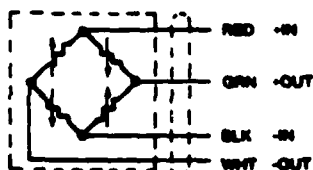
ELECTRICAL

SUPPLY VOLTAGE	15 Vdc
MAXIMUM SUPPLY VOLTAGE	18 Vdc
ELECTRICAL CONFIGURATION	Four-active-arm piezoresistive bridge in silicon
POLARITY	Positive output for increasing pressure
RESISTANCE	
Input	1 800 Ω , typical
Output	1 600 Ω , typical
Isolation	100 M Ω minimum at 50 Vdc, leads to case, leads to shield and shield to case

¹ Reference 0 dB = 2000 rms μ bar (rms dynamic) = 20×10^{-6} N/cm² rms = 20 μ Pa rms

Figure B4. Microphone specifications.

SPECIFICATIONS FOR MODEL 888M1 MICROPHONE



STANDARD TOLERANCE

INCHES	(MILLIMETRES)
X = ± 0.1	(X = ± 2.5)
.XX = $\pm .00$	(.XX = ± 0.8)

MECHANICAL

MOUNTING

Adhesive Bonding (RTV recommended)

MATERIAL EXPOSED TO MEASURAND MEDIA

Stainless steel, Parylene C and epoxy

CABLE

Integral, four conductor, shielded, Teflon-insulated conductors, gray PVC jacket, 30 in. (760 mm) long, .05 in. (1.3 mm) dia.

WEIGHT (EXCLUDING CABLE)

0.036 oz (0.8 g), cable weighs 0.036 oz/ft (3.4 g/m)

ENVIRONMENTAL

TEMPERATURE RANGE COMPENSATED MAXIMUM

-4°F to +212°F (-20°C to +100°C)
-66°F to +225°F (-64°C to +107°C)

VIBRATION

500 g pk, sinusoidal

SHOCK

10 000 g, 100 μ s half-sine

HUMIDITY, PER MIL-STD-883C, Method 1008, test condition B

Isolation resistance 100 M Ω at 50 Vdc

Figure B4. (Cont'd).

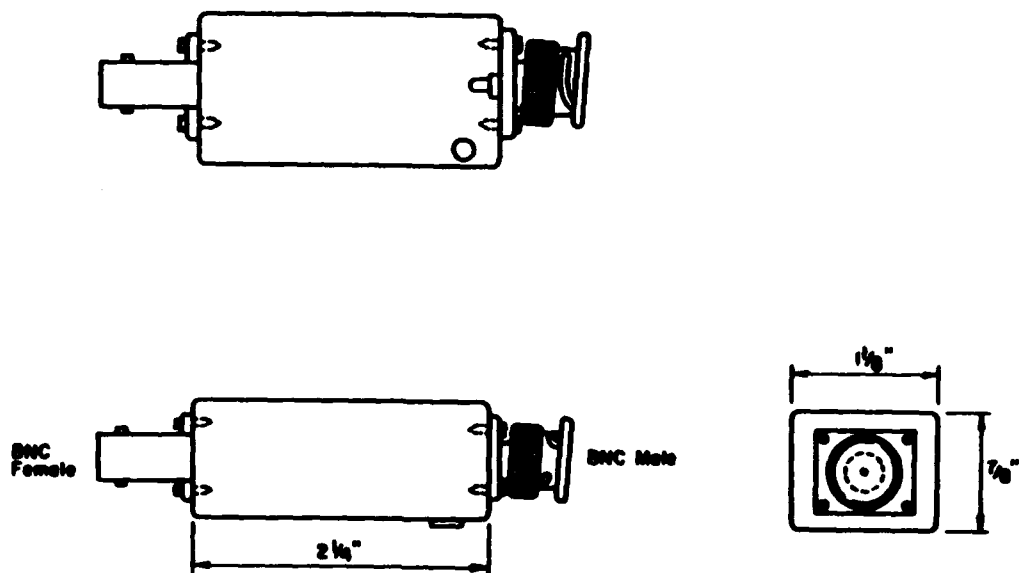


Figure B5. Piezoresistive preamp encasement.

APPENDIX C: ANALYZED DATA (BY EVENT)

Sessions:

Event	Weapon	1				2				3			
		Peak (Flat)	dB (Sec)	PSL/ Noise	CSEL/ Noise	Peak (Flat)	dB (Sec)	PSL/ Noise	CSEL/ Noise	Peak (Flat)	dB (Sec)	PSL/ Noise	CSEL/ Noise
1	C-4	116.4	-11.6	128.6 104.2	122.1 101.6	148.2	-11.9	123.5 104.1	123.3 101.5	151.6	-11.5	130.4 101.3	126.6 98.3
2	TOW									135.2	-12.0	112.3 97.1	110.0 94.5
3	TOW					122.7	-10.9	101.0 98.4	96.0 92.6			111.8 91.9	112.9 88.2
4	C-4	150.7	-11.6	130.3 104.7	125.1 102.3	148.3	-12.4	127.6 105.2	122.9 102.8	148.5	-12.0	128.3 101.1	123.7 98.8
5	TOW					125.6	-10.8	100.3 97.6	98.5 85.4	135.3	-12.0	110.9 90.4	108.5 88.1
6	TOW	146.3	-10.5	125.3 100.9	121.0 100.6	120.3	-10.8	102.3 96.8	95.3 85.2	137.7	-12.0	113.9 92.6	111.9 88.7
7	C-4	147.9	-11.4	129.3 105.8	123.5 102.8	147.7	-11.8	127.4 104.9	122.3 102.8	148.5	-12.0	128.8 101.9	124.5 98.3
8	C-4	148.7	-11.4	128.9 105.6	123.9 103.7	147.8	-11.8	128.9 105.3	123.3 102.9	150.8	-12.0	129.3 101.7	125.3 100.5

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4				5				6				7			
Peak (Flat)	dB (Sec)	PSL/ Noise	CSEL/ Noise	Peak (Flat)	dB (Sec)	PSL/ Noise	CSEL/ Noise	Peak (Flat)	dB (Sec)	PSL/ Noise	CSEL/ Noise	Peak (Flat)	dB (Sec)	PSL/ Noise	CSEL/ Noise
						132.1 98.2	124.8 98.1							121.6 102.5	120.6 100.0
				156.6	-12.0							115.5	-13.2		
						119.4 101.7	118.7 93.8								
				145.6	-11.5										
148.9	-12.4	115.0 98.5	114.2 96.5			117.9 93.9	116.3 98.8	129.2	-11.7	104.9 98.4	101.3 94.7				
		126.2	122.2			130.7	127.1			132.1	128.2			128.6	122.7
148.0	-12.0	104.5	105.4	154.1	-11.5	108.3	98.4	133.8	-12.4	107.8	106.1	147.8	-12.7	108.3	104.3
						118.2	117.2			108.1	108.3				
				144.2	-11.8	98.4	86.7	128.4	-11.4	94.0	98.4				
						119.9	119.3			104.3	108.3				
				147.4	-11.8	98.6	94.3	128.6	-11.4	98.7	98.4				
147.8	-12.0	128.9 104.7	122.0 102.7			131.5 101.9	127.8 98.2	134.6	-12.0	102.3 104.3	102.7 97.7	148.5	-12.7	128.9 102.3	128.3 104.6
		127.1	128.3			132.3	128.1			134.8	127.9			128.1	128.3
148.8	-12.4	108.7	108.8	136.6	-12.2	98.3	98.0	138.6	-12.0	102.3	98.5	148.3	-12.7	108.6	104.3

Station:

Event	Weapon	1				2				3			
		Peak (Ft)	dB (Sec)	FEEL/ Noise	CHEL/ Noise	Peak (Ft)	dB (Sec)	FEEL/ Noise	CHEL/ Noise	Peak (Ft)	dB (Sec)	FEEL/ Noise	CHEL/ Noise
1	C-4	152.3	-13.1	129.9 98.9	122.5 97.1	153.4	-12.7	127.9 104.6	124.9 102.4	151.5	-12.2	129.1 106.9	126.8 104.7
2	C-4	151.3	-13.1	129.4 101.6	126.6 101.6	151.6	-12.7	129.1 101.6	126.5 99.8	152.1	-12.3	129.7 101.5	127.4 99.5
3	Artillery Simulator	156.5	-14.2	111.1 92.6	110.1 95.0	140.1	-12.8	114.6 95.8	113.9 94.2	141.5	-12.3	115.9 96.6	115.4 96.4
4	Artillery Simulator	152.1	-14.2	108.1 94.6	106.1 90.5	142.5	-13.5	118.2 81.2	116.2 -	136.8	-12.4	112.7 96.6	115.4 86.5
5	Artillery Simulator	130.4	-14.2	105.5 85.4	103.6 80.6	133.3	-13.4	106.5 79.8	105.2 78.9	129.7	-12.4	101.8 81.8	102.5 78.6
6	Artillery Simulator	151.0	-14.2	107.4 84.9	105.7 82.2	130.3	-13.4	106.8 81.4	104.9 79.1	151.7	-12.4	110.0 82.6	108.8 79.4
7	Artillery Simulator	151.2	-14.2	108.1 84.8	106.9 81.9	132.1	-13.4	107.4 90.2	106.1 72.4	154.6	-12.4	108.4 83.9	108.6 80.1
8	C-4	152.4	-13.4	129.6 104.7	127.0 102.3	150.7	-13.4	127.7 102.4	- 98.9	152.5	-12.4	129.3 108.7	127.4 98.7
9	C-4	152.7	-13.4	129.8 105.4	127.0 103.1	152.1	-13.4	129.1 101.3	126.4 98.7	154.1	-12.4	129.9 108.8	127.8 98.8
10	Hand Grenade Simulator	153.8	-13.4	108.5 86.1	107.8 75.6	151.6	-13.4	106.9 76.8	106.1 71.9	150.6	-12.4	103.4 117.2	101.7 -
11	Hand Grenade Simulator	152.4	-13.4	106.5 80.3	105.6 74.9	132.3	-13.4	106.4 74.4	106.6 70.7	129.1	-12.4	101.3 -	99.5 117.2
12	Hand Grenade Simulator	154.5	-13.4	108.5 82.7	107.8 75.8	132.5	-13.4	107.1 83.2	106.5 76.4	129.7	-12.4	101.9 117.2	100.4 -
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Peak (Ft)	dB (Sec)	4		5		6		7		8		9	
		FEEL/ Noise	CHEL/ Noise	FEEL/ Noise	CHEL/ Noise	FEEL/ Noise	CHEL/ Noise	FEEL/ Noise	CHEL/ Noise	FEEL/ Noise	CHEL/ Noise	FEEL/ Noise	CHEL/ Noise
153.5	-12.7	130.6 104.5	125.8 91.6	131.2 95.5	128.9 98.4	150.6 92.0	128.5 88.8	147.4	-11.3	124.5 94.6			
154.8	-12.7	131.7 101.3	129.5 96.7	131.3 98.5	129.1 94.7	150.4 90.7	128.2 96.4	148.3	-12.1	125.4 94.9			
157.9	-12.7	113.4 97.3	112.7 95.3	111.0 96.6	110.2 96.0	154.5 94.3	109.0 91.4	151.5	-13.0	107.4 92.8			
156.6	-13.7	116.5 94.1	115.1 88.3	116.7 93.8	110.3 87.1	152.9 90.4	108.5 88.3	150.3	-13.0	106.8 78.1			
129.4	-13.7	102.8 71.8	101.9 78.6	104.9 78.3	108.6 77.6	150.8 88.5	108.1 77.4	122.1	-13.0	96.9 77.9			
157.8	-13.7	111.1 -	104.7 -	112.5 86.3	111.5 84.4	155.5 88.5	108.5 75.9	151.1	-13.0	107.0 78.3			
156.2	-13.7	119.5 88.3	108.8 -	110.9 86.6	110.1 76.2	152.9 81.3	107.8 77.2	129.1	-13.0	104.8 76.5			
158.8	-13.7	120.8 -	122.1 -	120.7 98.2	120.4 97.9	152.2 100.0	128.2 98.3	148.4	-11.9	128.0 92.4			
154.7	-13.7	120.2 -	122.1 -	121.2 98.4	120.9 94.4	152.7 98.6	127.3 96.2	148.3	-11.9	128.3 98.3			
151.8	-13.7	108.6 117.8	101.8 117.8	108.6 77.8	108.1 86.2	155.2 74.1	108.4 -	150.3	-12.1	104.4 88.9			
151.8	-13.7	108.8 -	98.3 117.8	109.4 97.3	108.7 78.9	154.6 88.1	108.2 77.3	150.4	-12.3	108.7 78.8			
151.8	-13.7	104.8 117.8	100.7 117.8	108.4 98.6	108.9 88.3	150.1 88.9	108.6 78.5	150.0	-12.3	108.7 88.8			

Station:

Event	Weapon	1				2				3			
		Peak (Flat)	dB (Soc)	FUEL/ Noise	CHEL/ Noise	Peak (Flat)	dB (Soc)	FUEL/ Noise	CHEL/ Noise	Peak (Flat)	dB (Soc)	FUEL/ Noise	CHEL/ Noise
13	Hand Grenade Simulator	132.6	-13.4	106.5 88.1	106.5 76.2	130.8	-13.4	106.1 79.6	104.2 70.9	131.9	-12.4	106.9 117.2	102.7 117.2
14	Hand Grenade Simulator	130.2	-13.4	105.8 84.4	104.5 75.2	130.8	-13.4	106.8 75.7	104.7 74.6	132.4	-12.4	104.4 117.2	102.9 117.2
15	C-4	152.8	-13.4	129.9 105.7	127.3 100.4	151.0	-13.4	128.7 100.1	125.9 98.3	148.2	-12.4	122.6 -	121.5 -
16	Artillery Flash Simulator	126.0	-13.4	100.8 86.4	99.0 80.8	124.9	-13.4	99.7 85.3	97.9 78.2	119.2	-12.1	92.5 -	92.5 -
17	Artillery Flash Simulator	136.3	-13.8	110.6 81.3	109.9 68.5	135.9	-13.4	110.3 78.6	109.3 76.1	136.9	-12.4	109.7 -	107.9 -
18	Artillery Flash Simulator	130.3	-11.9	106.8 78.7	117.8 75.8	129.9	-12.1	106.4 78.1	104.3 74.8	127.6	-12.4	99.6 -	99.6 -
19	C-4			129.6 107.5	126.9 105.0			129.9 108.2	127.6 99.4			124.2 -	122.9 -
20	C-4	152.2	-11.9			155.2	-12.1			150.2	-12.4		

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4				5				6				7			
Peak (Flat)	dB (Soc)	FUEL/ Noise	CHEL/ Noise	Peak (Flat)	dB (Soc)	FUEL/ Noise	CHEL/ Noise	Peak (Flat)	dB (Soc)	FUEL/ Noise	CHEL/ Noise	Peak (Flat)	dB (Soc)	FUEL/ Noise	CHEL/ Noise
130.0	-13.7	106.4 -	100.9 -	136.1	-13.0	110.6 78.0	100.9 77.2	133.6	-12.7	108.4 87.5	107.7 71.8	128.3	-12.3	105.8 78.6	103.0 70.0
132.0	-13.7	105.6 -	98.6 -	134.0	-13.0	100.0 85.2	100.4 73.9	132.4	-12.7	108.1 94.1	107.2 80.0	126.6	-12.3	102.4 83.3	101.5 71.2
132.0	-13.7	127.6 -	120.8 -	134.1	-13.0	130.9 96.9	135.6 94.3	132.9	-12.7	129.7 98.3	127.5 96.7	126.7	-12.3	124.1 92.2	121.3 88.5
125.1	-13.7	96.7 -	88.9 -	127.5	-13.0	104.7 82.1	100.4 76.8	126.6	-12.7	104.4 94.3	100.2 76.9	120.2	-12.3	95.4 76.7	93.8 72.9
137.0	-13.7	109.8 -	104.6 -	137.2	-13.0	112.0 -	-	136.6	-12.7	111.6 70.2	110.9 68.0	130.0	-12.3	106.3 71.8	104.7 68.1
132.5	-13.7	104.4 -	98.7 -	132.0	-13.0	107.4 82.3	108.3 74.3	130.0	-12.7	106.7 81.4	106.3 77.3	124.0	-12.3	104.0 76.4	100.1 72.3
				134.0	-13.0	131.0 97.3	135.7 97.9	130.2	-12.7	130.8 108.7	127.5 97.4	127.7	-11.6	124.3 98.3	121.8 92.0

Station:

Event	Weapon	1				2				3			
		Peak (Flat)	dB (Sec)	FSEL/ Noise	CSEL/ Noise	Peak (Flat)	dB (Sec)	FSEL/ Noise	CSEL/ Noise	Peak (Flat)	dB (Sec)	FSEL/ Noise	CSEL/ Noise
21	C-4	134.1	-12.6	131.5 105.7	106.5	130.2	-13.2	130.4 101.8	90.1	130.2	-12.7	130.3 90.8	134.3 90.7
22	C-4	134.2	-12.6	131.5 106.9	104.3	133.6	-13.2	130.6 100.3	90.7	130.6	-12.8	130.3 103.6	130.2 90.7
23	LAW	129.1	-12.6	105.5 90.5	102.5 80.6	133.5	-12.8	107.9 81.1	106.7 70.6	144.2	-12.8	120.3 81.2	119.6 79.4
24	LAW	129.5	-12.6	104.5 91.2	103.8 80.9	132.0	-12.8	106.3 81.1	105.3 70.1	132.5	-13.1	114.3 86.2	117.5 81.2
25	LAW	131.6	-12.6	104.5 90.7	103.5 80.4	133.4	-12.8	106.9 82.2	105.4 79.8	141.9	-13.1	114.2 81.6	117.3 79.0
26	C-4	134.1	-12.6	129.3 104.4	120.9 103.9	133.1	-12.8	130.2 103.3	127.8 90.2	132.9	-13.1	130.3 90.1	120.0 90.1
27	C-4	133.9	-12.6	131.1 105.8	120.7 103.8	133.1	-12.8	130.1 100.9	127.8 90.7	132.7	-13.1	130.3 102.2	120.1 90.7
28	LAW	130.8	-12.6	105.4 90.4	104.7 80.5	132.9	-12.8	106.7 80.9	105.7 80.0	140.1	-13.1	116.5 83.7	115.6 83.1
29	LAW			104.8 89.2	103.7 87.1	132.9	-12.8	106.9 81.1	105.8 77.8	130.1	-13.1	116.9 95.1	115.8 80.5
30	LAW	130.2	-12.6	131.1 105.7	120.8 106.0	133.9	-12.8	130.1 99.6	127.7 97.1	132.7	-13.1	130.0 100.2	127.8 95.8
31	C-4	133.9	-12.6	131.3 107.4	120.2 104.2	132.9	-12.8	130.1 100.4	127.6 97.6	131.8	-13.1	129.4 101.8	127.1 90.2

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4				5				6				7			
Peak (Flat)	dB (Sec)	FSEL/ Noise	CSEL/ Noise	Peak (Flat)	dB (Sec)	FSEL/ Noise	CSEL/ Noise	Peak (Flat)	dB (Sec)	FSEL/ Noise	CSEL/ Noise	Peak (Flat)	dB (Sec)	FSEL/ Noise	CSEL/ Noise
133.0	-12.6	130.9 103.2	120.5 100.3	135.0	-12.4	131.1 102.2	130.2 90.4	130.1	-12.2	130.2 97.6	134.1 90.1	132.5	-12.8	130.2 100.9	131.6 102.4
133.2	-12.6	130.6 101.6	120.0 100.5	134.1	-12.4	131.3 101.3	120.8 97.5	130.4	-12.2	130.4 100.1	130.1 102.1	131.7	-12.8	129.7 100.9	130.0 101.9
144.4	-12.6	121.7 91.2	120.7 80.9	140.8	-12.4	116.1 -	115.1 71.9	130.0	-12.2	100.9 100.1	84.4 82.5	137.3	-12.8	115.4 77.6	114.3 70.0
140.1	-12.6	122.6 90.7	121.5 80.4	143.6	-12.4	119.3 -	118.3 -	132.5	-12.2	106.9 84.8	106.9 82.7	130.1	-12.8	116.3 81.1	113.2 70.9
143.9	-12.6	122.3 91.2	121.5 80.7	143.6	-12.4	119.4 70.2	118.4 -	132.1	-12.2	107.0 84.3	106.2 82.7	137.9	-12.8	116.1 77.7	115.1 70.9
132.8	-12.6	130.1 105.1	127.6 102.5	134.0	-12.4	130.3 87.9	127.9 91.7	133.6	-12.2	130.6 106.1	120.4 104.6	131.7	-12.8	120.6 100.1	120.4 102.2
132.4	-12.6	129.9 102.3	127.3 100.7	130.8	-12.4	131.1 92.0	120.7 90.3	130.5	-12.2	130.4 100.1	120.4 101.4	131.7	-12.8	120.0 102.8	127.4 102.2
				143.3	-12.4	119.3 87.1	118.3 80.3	132.0	-12.2	107.0 80.3	106.7 82.2	137.0	-12.8	114.7 70.9	113.5 71.1
				140.0	-12.7	119.2 90.2	118.2 80.1	131.3	-12.2	106.3 80.4	106.6 80.7	130.0	-12.8	113.0 77.4	113.0 70.0
132.0	-12.6	130.9 102.2	120.7 90.8	134.7	-12.7	131.6 101.6	120.4 90.1	130.9	-12.2	130.3 100.3	120.4 90.0	131.7	-12.8	120.3 100.0	120.7 102.0
				134.3	-12.7	131.4 102.0	120.1 90.5	134.0	-12.2	131.5 100.0	120.5 97.0	130.7	-12.8	120.5 101.7	120.5 102.0

APPENDIX D: DATA REDUCTION TABLES

The C-4 blasts just before and just after each weapon event or series of events were averaged to form a correction value that would convert the C-4 to a perfect hemispherical source. Each weapon was then averaged by station and

subtracted from this correction value to give the corrected values for each weapon at each station. These values were then normalized to the 180° position and used to form the entries for the BNOISE 3.2 program.

Table D1
Reduced Data — LAW

C-4 Energy Averages 1 Through 4 (Raw C-4 Values)	First LAW Set (Raw Value)	Correction	Corrected Value	Value Ref 5 lb of C-4
128.9	103.5	+9	104.2	-25.6
128.0	105.8	+1.8	107.6	-22.2
130.6	118.5	-.8	117.5	-12.3
127.9	121.3	+1.9	123.2	-4.6
131.3	117.5	-1.5	116.0	-13.8
130.6	106.8	-.8	106.0	-23.8
129.8				

C-4 Energy Averages 5 Through 6 (Raw C-4 Values)	Second LAW Set (Raw Value)	Correction	Corrected Value	Value Ref 5 lb of C-4
128.9	104.2	-.6	103.6	-24.7
127.8	105.8	+.5	106.3	-22.0
127.8	115.7	+.5	116.2	-12.1
127.3		+1.0		
128.8	118.5	-.5	117.8	-10.5
128.7	106.2	-.4	105.8	-22.5
128.3				

Average LAW Data Ref:
5 lb of C-4

-25.1
-22.1
-12.2
-4.6
-11.8
-23.1

Average LAW Data Ref: 5 lb of C-4
(corrected to be symmetrical)

-25.1
-22.6
-12.0
-4.6
-12.0
-22.6
-12.2

Average LAW Data Ref: 5 lb
of C-4 with 0 dB
to Ref: + 6.6 dB

-18.5 (0°)
-16.0 (60°)
-5.4 (120°)
0.0 (180°)
-5.4 (240°)
-16.0 (300°)
-3.6

Values for Table 8 (BNOISE 3.2 Input Data)

0° (-18.5)	180° (0.0)
30° (-17.1)	210° (-1.9)
60° (-16.0)	240° (-5.4)
90° (-8.0)	270° (-8.0)
120° (-5.4)	300° (16.0)
150° (-1.9)	330° (-17.1)

A = -12.2 + 119 = 106.8

B = 0

Average = -5.6

Table D2
Reduced Data — TOW

First and Second C-4 Energy Averages (Raw C-4 Values)	First TOW Set (Raw Value)	Correction	Corrected Value	Value Re: 5 lb of C-4
124.1	—	+1.7	—	—
125.1	96.0	+2.7	98.7	-27.1
125.4	111.7	+4	112.1	-13.7
122.2	114.2	+3.6	117.8	-8.0
128.0	117.7	-2.2	115.5	-10.3
<u>128.2</u>	101.3	-2.4	98.9	-26.9
125.8				

Second and Third C-4 Energy Averages (Raw C-4 Values)	Second TOW Set (Raw Value)	Correction	Corrected Value	Value Re: 5 lb of C-4
124.3	121.0	+1.5	122.5	-3.3
122.9	97.9	+2.9	100.8	-25.0
124.6	110.9	+1.2	112.1	-13.7
122.6	—	+3.2	—	—
128.1	118.4	-2.3	116.1	-9.7
<u>128.3</u>	102.1	-2.5	99.6	-26.2
125.8				

Average TOW Data Re: 5 lb of C-4 (dB)	Average TOW Data Re: 5 lb of C-4 (dB) (corrected to be symmetrical (dB))	Adjusted Average TOW Data Re: 5 lb of C-4 with 0 db to Rear + 8.0 dB
-3.3 *(-30.0)	-30.0	-22.0 (0°)
-25.9	-26.2	-18.2 (60°)
-13.7	-11.5	-3.5 (120°)
-8.0	-8.0	0.0 (180°)
-10.0	-11.5	-3.5 (240°)
-26.5	<u>-26.2</u>	<u>-18.2 (300°)</u>
	-12.9	-1.9

Values for Table 3 (BNOISE 3.2 Input Data)

0° (-22.0)	180° (0.0)
30° (-18.7)	210° (-1.4)
60° (-18.2)	240° (-3.5)
90° (-6.4)	270° (-6.4)
120° (-3.5)	300° (18.2)
150° (-1.4)	330° (-18.7)

A = -12.9 + 119 = 106.1
B = 0
Average = -4.9

*-3.3 (dB) is more a measure of the rocket passing near the microphone than a measure of the weapon firing noise. Hence, it is excluded from further calculation and replaced by -30.0 (dB) since the LAW data show the front to be the quietest position.

Table D3
Reduced Data — Artillery Simulator

C-4 Energy Averages 1 Through 4 (Raw C-4 Value)	First Artillery Simulator Set (Raw Value)	Correction	Corrected Value
127.0	107.0	+4	107.4
126.0	111.9	+1.4	113.3
127.4	112.3	0.0	112.3
126.8	110.6	+6	111.2
128.8	109.9	-1.4	108.5
<u>128.1</u>	<u>107.8</u>	<u>-7</u>	<u>107.1</u>
127.4			110.6
Corrected Average	110.6		
C-4 Average	<u>-127.4</u>		
	-16.8	Value re: 1-1/4 lb of C-4	
	<u>-5.0*</u>		
	-21.8	Value re: 5 lb of C-4	

$A = -21.8 + 119 = 97.2 = \text{Value for Table 3 (BNOISE 3.2 Input Data)}$

*The -5.0 dB shift from Figure 17 of CERL TR N-98 plus the 119 dB converts the data to re: 5 lb of C-4 set off on the ground at 250 m.

Table D4
Reduced Data — Artillery Flash Simulator

First and Second C-4 Energy Averages (Raw C-4 Value)	Artillery Flash Simulator Set (Raw Value)	Correction	Corrected Value
127.1	113.7	+1.2	114.9
126.8	106.1	+1.5	107.6
122.3	103.8	+6.0	109.8
120.8	100.9	+7.3	108.4
133.4	104.3	-5.1	99.2
<u>127.5</u>	<u>107.1</u>	<u>+0.7</u>	<u>107.8</u>
128.3			110.0
Corrected Average	110.0		
C-4 Average	<u>128.3</u>		
	-18.3	Value re: 1-1/4 lb of C-4	
	<u>-5.0*</u>		
	-23.3	Value re: 5 lb of C-4	

$A = -23.3 + 119 = 95.7 = \text{Value for Table 3 (BNOISE 3.2 Input Data)}$

*The -5.0 dB shift from Figure 17 of CERL TR N-98 plus the 119 dB converts the data to re: 5 lb of C-4 set off on the ground at 250 m.

Table D6
Reduced Data — Hand Grenade Simulator

C-4 Energy Averages 2 Through 4 (Raw C-4 Value)	Hand Grenade Simulator Set (Raw Value)	Correction	Corrected Value
127.1	106.4	+9	107.5
126.2	105.6	+1.8	107.5
126.3	101.6	+1.7	105.5
121.5	100.6	+6.5	107.1
132.3	108.7	-4.3	104.4
<u>127.7</u>	<u>108.7</u>	<u>+9</u>	<u>109.0</u>
128.0			106.1

Corrected Average	106.8	
C-4 Average	<u>-128.0</u>	
	-21.3	Value re: 1-1/4 lb of C-4
	<u>-5.0*</u>	
	-26.2	Value re: 5 lb of C-4

A = -26.2 + 119 = 92.8 = Value for Table 3 (BNOISE 3.2 Input Data)

*The -5.0 dB shift from Figure 17 of CERL TR N-98 plus the 119 dB converts the data to re: 5 lb of C-4 set off on the ground at 250 m

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